- thermonuclear ("hydrogen") - three-phase or three-stage explosive devices in which three physical processes, localized in different areas of space, sequentially develop. A separate category should include three-stage thermonuclear weapons used to create ultra-high-power thermonuclear explosive devices (with a power from several, presumably from 2.5-5 megatons to tens of megatons. This is due to the fact that 1 fission stage cannot provide a sufficient amount of energy X-ray radiation, which is necessary to ensure the explosion of "large" thermonuclear stages. In three-stage devices, fission stage 1 (with an explosion power of up to tens of kilotons) is used for radiation implosion of the 2 ("small") thermonuclear stage (with an explosion power of several hundred kilotons).), and already the radiation of this 2nd thermonuclear stage (together with the radiation of the 1st stage) is used for the radiation implosion of the 3rd ("large") thermonuclear stage, with an explosion power from 2.5-5 megatons to many tens of megatons. An example of a three-stage weapon created in the USSR. was the so-called "Tsar Bomb" (AN-602), in which 2 small 1 fission stages (with an explosion power of up to tens of kilotons) were used for radiation implosion of 2 ("small") thermonuclear 2 stages (with an explosion power of 750 kilotons), and already the radiation from these 2 thermonuclear stages (together with the radiation from 1 stage) was used for the radiation implosion of the 3 ("large") thermonuclear stage (with an explosion power from 50 megatons to 100 megatons). In the Tsar Bomba (AN-602), the first two and two second stages were placed symmetrically on 2 sides of the third ("large") thermonuclear stage, according to the so-called "bifilar" scheme.

Using the same principle that was used to create three-phase or three-stage explosive devices, it is possible to create thermonuclear weapons with an even greater number of stages, for example, 4 or more stages, with a yield of hundreds and thousands of megatons (gigatons), but for a variety of reasons, no there is no practical need for this.

The thermonuclear fusion reaction, as a rule, develops inside a fissile assembly and serves as a powerful source of additional neutrons. Only early nuclear devices in the 1940s, a few cannon-assembled bombs in the 1950s, some nuclear artillery shells, and possibly products from nuclear-weak states (South Africa, Pakistan, North Korea) do not use fusion as an amplifier the power of a nuclear explosion or the main source of explosion energy.

The second stage of any thermonuclear explosive device can be equipped with a tamper - a neutron reflector. The tamper is made from ^{238}U, which is effectively fissioned by fast neutrons from the fusion reaction. This results in a multiple increase in the total power of the explosion and a monstrous increase in the amount of radioactive fallout. After the famous book " Brighter than a Thousand Suns ," written by R. Jung in 1958, "hot on the heels" of the Manhattan Project , this kind of "dirty" thermonuclear ammunition is quite often (at the suggestion of R. Jung) called FFF (fission-fusion-fission; division-fusion-division) or three-phase. However, this term is not entirely correct and should not be used. Almost all "FFF" are two-phase and differ only in the tamper material, which in "clean" ammunition can be made of lead, tungsten, etc., and in "dirty" ammunition from ^{238}U. According to information from the investigation of scandals related to nuclear espionage , the tamper in modern small-sized and powerful ammunition is made of ^{235}U, which is effectively divided from any (fast and slow) neutrons of the fusion reaction, and will significantly increase the explosion power of such ammunition, compared to a tamper made of ^{238}U. Also a 2nd stage tamper can be made, in addition to ^{238}U, or from enriched uranium with varying degrees of enrichment ^{235}U, or from ^{239}Pu, and various combinations of the above materials.

An exception is devices such as Sakharov's "Sloika" , which should be classified as single-phase with boosting, although they have a layered structure of the explosive charge (plutonium core - lithium-6 deuteride layer - uranium-238 layer). In the USA, such a device was called "Alarm Clock". The scheme of sequential alternation of fission and fusion reactions is implemented in two-phase ammunition, in which up to 6 layers can be counted with a very "moderate" power. An example is the relatively modern W88 missile warhead , in which the first section (primary) contains two layers, the second section (secondary) has three layers, and another layer is a shell of uranium-238 common to the two sections (see figure).

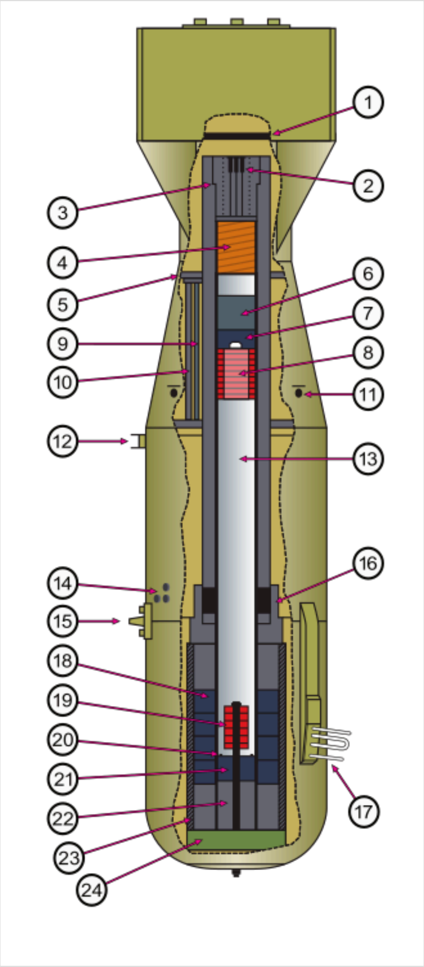
Sometimes neutron weapons are classified into a separate category - low-power two-phase ammunition (from 1 kt to 25 kt), in which 50-75% of the energy is obtained through thermonuclear fusion. Since the main carrier of energy during fusion is fast neutrons, during the explosion of such ammunition the neutron yield can be several times higher than the neutron yield during explosions of single-phase nuclear explosive devices of comparable power. Due to this, a significantly greater weight of damaging factors such as neutron radiation and induced radioactivity is achieved (up to 30% of the total energy output), which can be important from the point of view of the task of reducing radioactive fallout and reducing destruction on the ground with high efficiency of use against tank troops and manpower. There are mythical ideas that neutron weapons only affect people and leave buildings intact. The destructive impact of an explosion of a neutron munition is hundreds of times greater than that of any non-nuclear munition.

The power of a nuclear charge is measured in TNT equivalent - the amount of trinitrotoluene that must be detonated to produce the same energy. It is usually expressed in kilotons (kt) and megatons (Mt) (1 kt = 1000 t, 1 Mt = 1,000,000 t). The TNT equivalent is conditional: firstly, the distribution of the energy of a nuclear explosion over various damaging factors significantly depends on the type of ammunition, and, in any case, is very different from a chemical explosion. Secondly, it is simply impossible to achieve complete combustion of the appropriate amount of chemical explosive.

It is customary to divide nuclear weapons into five groups according to their power:

- ultra-small - less than 1 kt ;
- small (1-10 kt);
- medium (10 - 100 kt);
- large (high power) - from 100 kt to 1 Mt;
- extra-large (extra-high power) - over 1 Mt.

Options for detonation of nuclear weapons

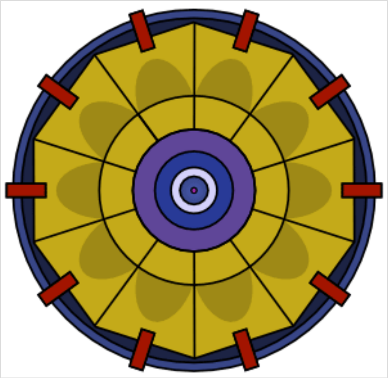


L-11 “Little Boy” ammunition device : **1** — armor plate, **2** — Mark-15 electric fuses, **3** — breech of a gun barrel with a plug, **4** — bags of cordite , **5** — barrel reinforcement pipe, **6** — steel back of the projectile, **7** - tungsten carbide projectile tray, **8** - uranium-235 rings, **9** - leveling rod, **10** - armored pipe with electrical wiring, **11** - barometric sensor ports, **12** - electrical connectors, **13** - 6.5-inch

mm caliber shortened to 1.8 m. In this case, the uranium “target” was a cylinder with a diameter of 100 mm and a mass of 25.6 kg, onto which, when fired, a cylindrical “bullet” weighing 38.5 kg with a corresponding internal channel was advancing. This, at first glance, strange design was chosen to reduce the neutron background of the target: it was not located close to it, but at a distance of 59 mm from the neutron reflector (tamper). As a result, the risk of premature onset of the so-called. " fizzy " was reduced to a few percent.

Later, based on this scheme, the Americans produced 240 artillery shells in three production series. These shells were fired from a conventional cannon . By the end of the 1960s, all these shells were eliminated due to the great danger of nuclear self-detonation.

Implosive scheme



The principle of operation **of the implosive detonation scheme** is that conventional explosive charges explode along the perimeter of the fissile substance, which create a blast wave that “compresses” the substance in the center and initiates a chain reaction.

An implosive detonation scheme uses the compression of fissile material by a focused shock wave created by the explosion of chemical explosive charges. So-called explosive lenses are used to focus the shock wave . Detonation is carried out simultaneously at many points with high precision. This is achieved using detonation wiring: from one fuse, a network of grooves filled with explosives radiates across the surface of the sphere. The shape of the network and its topology are selected in such a way that at the end points the blast wave through the holes in the sphere reaches the centers of the explosive lenses simultaneously (at the first charges, each lens was detonated by its own detonator, for which the control device had to apply a synchronous impulse to all). The formation of a converging shock wave was ensured by the use of explosive lenses from “fast” and “slow” explosives - Composition B (Russian composition B, abbreviated “comp B”) - a mixed explosive, which is a suspension of hexogen powder (RDX) in a trinitrotoluene melt (TNT) and boratol (a mixture of trinitrotoluene with barium nitrate), and some additives (see animation). The creation of such a system for the placement of explosives and detonation was at one time one of the most difficult and time-consuming tasks. To solve it, it was necessary to perform a gigantic amount of complex calculations in hydro- and gas dynamics. According to this scheme, the first nuclear explosive device "Gadget" (English *gadget* - device) was executed, detonated on the tower in order to test in practice the operation of the implosion circuit during the tests " Trinity " ("Trinity") on July 16, 1945 at a test site not far from Alamogordo town in New Mexico . The second of the atomic bombs used, “ Fat Man ,” dropped on Nagasaki on August 9, 1945, was executed according to the same scheme. In gun barrel, **14** - connectors fuse, **15** — rigging eyelet, **16** — target adapter, **17** — antennas, **18** — tungsten carbide sleeve, **19** — uranium-235 target, **20** — polonium-beryllium initiators, **21** — tungsten carbide plug, **22** — anvil, **23** — target sleeve made of steel K-46, **24** — nose plug with a diameter of 15 inches

fact, Gadget was a stripped-down prototype of Fat Man. This atomic bomb used a so-called “hedgehog” (English *urchin*) as a neutron initiator (for technical details, see the article “ Fat Man ”). Subsequently, this scheme was recognized as ineffective, and the uncontrolled type of neutron initiation was almost never used in the future.

Boosterization of a nuclear explosion

The so-called *boosterization of a nuclear explosion with a deuterium-tritium mixture* was conceived by American nuclear scientists back in 1947-49. But the use of this scheme became possible only in the 50s. Thus, the Orange Herald nuclear bomb with a power of 720 kt from 17 kg ^{235}U was tested by British specialists on May 31, 1957 and had lithium-6 hydrides in the assembly center , but with deuterium (lithium deuteride) and tritium (lithium tritide) (LiD/ LiT).

In modern nuclear weapons (based on fission reactions), a small amount (grams (on the order of 3-6 grams)) of thermonuclear fuel (deuterium and tritium) in the form of gas (due to the decay of tritium) is usually placed in the center of a hollow assembly (pumped before detonation). in nuclear weapons must be updated every few years).

During a nuclear explosion, this deuterium-tritium gas inevitably heats up and is compressed at the very beginning of the fission process to such a state that a thermonuclear fusion reaction begins in it, which is tiny in volume, which gives a slight increase in the total energy output - for example: 5 grams of such gas during fusion reactions provide an increase of only 1.73% of the total explosion power of 24 kt for a small nuclear bomb made from 4.5 kg of plutonium. But neutrons during boosterization allow 1.338 kg of plutonium, or 29.7% of the total mass of plutonium, to completely react in the fission reaction - in bombs without boosterization, the proportion of fully reacted plutonium is even smaller (about 13% - like the “ Fat Man ” bomb). Numerous high-energy (fast) neutrons released from this small-volume fusion reaction (right in the center of the assembly) initiate new chain reactions throughout the entire volume of the assembly and thereby compensate for the loss of neutrons leaving the active reaction zone in the outer parts of the assembly. Therefore, this device is often referred to in diagrams as *a deuterium-tritium neutron initiator* [4] [5] .

Neutrons during boosting have an energy of about 14 MeV, which is 14 times the energy of “ordinary” neutrons from a fission reaction. Therefore, when colliding with a nucleus of fissile material, they produce more secondary neutrons (4.6 versus 2.9 for the case of Pu-239 plutonium) [6] .

The use of such initiators leads to a manifold increase in the energy yield from the fission reaction and more efficient use of the main fissile substance.

By changing the amount of a gas mixture of deuterium and tritium pumped into the charge, it is possible to obtain ammunition with a widely adjustable explosion power (see Variable power nuclear warhead).

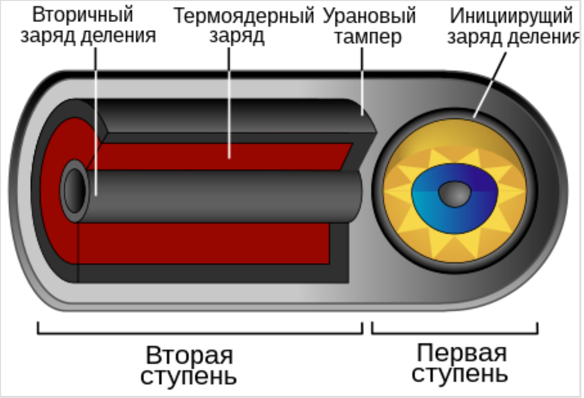
Swan type design

Nuclear weapons assembly form

The described scheme of spherical implosion is archaic and has hardly been used since the mid-1950s. The principle of operation of the “Swan” type design (English *swan* - swan) is based on the use of a fissile assembly of a special shape, which, in the process of implosion initiated at one point by one fuse, is compressed in the longitudinal direction and turns into a supercritical sphere. The shell itself consists of several layers of explosive with different detonation rates, which is made on the basis of an alloy of octogen and plastic in the required proportion and filler - polystyrene foam, so that between it and the nuclear assembly located inside there remains a space filled with polystyrene foam. This space introduces the necessary delay due to the fact that the speed of detonation of the explosive exceeds the speed of the shock wave in the polystyrene foam. The shape of the charge strongly depends on the detonation speed of the shell layers and the speed of propagation of the shock wave in polystyrene, which is hypersonic under these conditions. The shock wave from the outer layer of explosive reaches the inner spherical layer simultaneously over the entire surface. A significantly lighter tamper is made not from ^{238}U, but from beryllium, which reflects neutrons well. It can be assumed that the unusual name of this design - “Swan” (first test - Inca in 1956) was suggested by the shape of the swan’s neck. Thus, it turned out to be possible to abandon spherical implosion and, thereby, solve the extremely difficult problem of submicrosecond synchronization of fuses on a spherical assembly and thus simplify and reduce the diameter of implosion nuclear weapons from 2 m in the “ Fat Man ” to 30 cm or less in modern nuclear weapons. In case of abnormal operation of the detonator, there are several safety measures that prevent uniform compression of the assembly and ensure its destruction without a nuclear explosion. The measures are based on the fact that they tend to make the structure “semi-disassembled” in storage mode. “Additional assembly” is performed automatically, upon command - this operation is called the cocking operation.

Thermonuclear ammunition

The power of a nuclear charge operating solely on the principle of fission of heavy elements is limited to tens of kilotons. Energy output (eng. *yield*) of a single-phase nuclear explosive device, enhanced by thermonuclear fuel inside a fissile assembly (Boosted fission weapon), can reach hundreds of kilotons. It is practically impossible to create a single-phase nuclear explosive device with megaton or higher power; increasing the mass of fissile material does not solve the problem. The fact is that the energy released as a result of the chain reaction inflates the assembly at a speed of about 1000 km/s , so it quickly becomes subcritical and most of the fissile material does not have time to react and is simply scattered by a nuclear explosion. For example, in the “ Fat Man ” dropped on the city of Nagasaki, no more than 20% of the 6.2 kg of plutonium charge reacted , and in the “ Baby ” with a cannon assembly that destroyed Hiroshima, only 1.4% of the 64 kg of uranium enriched to approximately 80% decayed . The most powerful single-phase munition in history is the British one, detonated during the Orange Herald tests in 1957 , reaching a yield of 720 kt . A polygonal circuit of a single-phase nuclear explosive



Teller-Ulam design for a two-phase munition (“thermonuclear bomb”).